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Using Mobile Phones for Nutrition Surveillance: A Review of Evidence

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USING MOBILE PHONES FOR NUTRITION SURVEILLANCE: A REVIEW OF EVIDENCE

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List of Abbreviations

GPS	Global Positioning System
GSMA	Global System for Mobile Communications Association
SMS	Short Message Services
WHO	World Health Organisation

1. Introduction

1.1 Background

Undernutrition remains one of the major challenges in low-income countries. The consequences of undernutrition in early childhood are especially devastating and can lead to lifelong physical and mental impairments. In May 2012, health leaders worldwide adopted the Maternal, Infant and Young Child Nutrition Plan at the 65th World Health Assembly. This includes committing to reduce the number of stunted children in the world by 40 per cent by 2025.

Nutrition surveillance – or the systematic and periodic collection of information on nutrition – is vital to the capacity of governments and other agencies to track their progress towards reducing undernutrition, to promoting the accountability of their actions and to improving their ability to respond promptly to rapid changes in nutrition status brought about by food price volatility and other shocks. Nutritional surveillance data may also help to empower civil society and enhance their capacities to make claims on government and other agencies, to monitor the commitment and actions of those agencies and to campaign around nutrition to move it higher up the policy agenda.

However, nutrition surveillance is expensive and logistically laborious and therefore often non-existent in resource-low countries. Surveillance systems are also constrained by time-consuming and error-prone paper-based data collection followed by manual data entry. Data transfer may take months to reach a level at which they can be analysed and lack of human resources to accomplish analysis often leads to further delays and often underuse of surveillance data. Consequently, monitoring of nutrition outcomes in real time and timely response to nutritional crises is often impossible.

Mobile phone technologies could help to address many of these challenges. The potential benefits of using mobile phones for surveillance are:

- Lower costs of data collection and transfer
- Faster data transmission, analysis and dissemination
- Improved data quality
- More transparent and inclusive data collection processes with the possibility of immediate feedback to households and communities.

Falling prices and increasing network coverage have resulted in high penetration of mobile phone technology even in remote areas of the world. It is estimated that more than three-quarters of the world's population now have access to a mobile phone (World Bank 2012). In the last decade the number of mobile phone subscriptions increased explosively in low- and middle-income countries from 4 per cent of the population having a subscription in 2000 to more that 72 per cent in 2010. In the 36 countries with the highest burden of undernutrition[1] mobile phone penetration ranges from 14 per cent of the inhabitants having a subscription in Burundi to more than 100 per cent in Egypt, Guatemala, Peru, South Africa and Vietnam (see Appendix 1).

In this context, there has been an increasing interest in the potential of mobile phones to promote development, improve livelihoods and alleviate poverty. The United Nations Development Programme points out that 'Mobile phones can enhance pro-poor development ... in health, education, agriculture, employment, crisis prevention and the environment' (UNDP 2012). Mobile phones have been used to improve access to and dissemination of

[1] Identified in the 2008 *Lancet* Series on Maternal and Child Undernutrition (Black, Allen, Bhutta *et al*. 2008)

information, facilitate training, accelerate data gathering and monitoring, support resource allocation and improve service delivery even in remote areas (World Bank 2012).

1.2 Aims of the evidence review

This report sets out to critically review the evidence base on the impact of using mobile phone technology for nutrition (and other) surveillance.[2] By doing so, the report can offer a starting point for international donors, local practitioners and others who consider the application of mobile phones to facilitate surveillance. The evidence review also aims to identify gaps in the current knowledge base and to highlight areas where future research and analysis are necessary.

The review will begin by critically examining the extent and quality of existing evidence on the impact of using mobile phone technology for nutrition surveillance and surveillance in related sectors.

Drawing on the identified evidence base, the review will then assess:

1. whether mobile phones have the potential to improve the effectiveness of surveillance with regards to timeliness, costs, data quality, data analysis and visualisation; and,
2. whether the use of mobile phones can influence/strengthen the empowering effect of nutrition (and other) surveillance.

This is followed by a summary of evidence on (3) challenges and (4) enabling factors for a successful implementation of mobile phone-based surveillance systems.

[2] In preparation of the review process, an initial scoping of available evidence was carried out. This stocktaking exercise suggested a lack of documented evidence on the use of mobile phones for nutrition surveillance. Consequently, it was decided to also include evidence on the use of mobile phones for surveillance in related sectors including health and agriculture.

2. Methodology

While this is not a systematic review[3], the key principles of rigour, consistency and transparency were applied when gathering, appraising and synthesising the evidence base.

The scope of the review was on:

Surveillance: the focus has been on systematic and periodic (routine) collection of information on nutrition, health status or agriculture.

Mobile phones: the focus has been on the application of mobile phones (e.g. basic mobile phone, smartphone) and modalities offered by mobile phone technology (e.g. text messaging (SMS), voice data transmission).

Country-specific focus: the focus has been on evidence on mobile phone-based surveillance in low- and middle-income countries.

This review was informed by targeted searches of electronic databases (Medline, SCOPUS, Web of Knowledge, ASSIA and Google Scholar search engine). A search was also conducted for reports from the World Bank, UNICEF, the Food and Agriculture Organization (FAO), the World Health Organization (WHO) and other relevant governmental and non-governmental organisations and international bodies. Company websites of mobile phone operators (e.g. mobile handset producers, network providers, software companies) as well as interest organisations of the mobile phone technology sector (e.g. GSMA) were also scanned. Additional evidence was identified from the reference lists of the identified studies.

Key search terms were determined in an initial scoping of the evidence base and included variations of the terms: cell phone, cellular phone, texting, text messaging, short message service, SMS, mobile phone, health, disease, agriculture, nutrition, monitoring and surveillance.

Given the aims of this review, only studies and reports that assessed the impact of using mobile phone technology for nutrition (or related) surveillance were included. Studies that merely offered descriptions of the design and/or the general operation and functionalities of mobile phone-based surveillance systems were excluded.

Only evidence published in the English language was considered. Studies and reports published before January 2013 were included. The quality of the available evidence was assessed based on the rigour of the study design (e.g. clear specification of study objectives and outcomes, ethical concerns) and validity (e.g. biases in sample selection, measurements). No study was excluded based on the quality rating. Data extraction was guided by the overarching aims of this review and a narrative approach was chosen for the evidence synthesis.

[3] Based on our initial scoping exercise it was decided that a full systematic review would not be feasible at this time due to the limited availability of good-quality evidence.

3. Extent and quality of evidence on the impact of using mobile phones for surveillance

In the following section an overview of the identified evidence will be given. To facilitate the understanding of evidence analysis presented in the following sections, an introduction to the basic technical features of the mobile phone-based surveillance will be provided. The section concludes with a brief critical appraisal of the identified evidence.

3.1 Extent of evidence

The search identified over 30 studies that provide a detailed description of technological and operational aspects of mobile phones that facilitate surveillance. However, only nine studies that assessed the impact of using of mobile phones for surveillance were found and consequently included in this review. These studies were all pilot studies with a short timeframe that described the implementation of a mobile phone-based system and then discussed the feasibility of using mobile phone technology for surveillance. No rigorous process or impact evaluation using, for example, randomized controlled designs or pre–post comparison, could be identified. The evidence was presented as peer-reviewed publications or project reports.

Mobile phones use was mainly evaluated in the context of infectious disease surveillance (in both animals and humans) (see Table 3.1). Only two studies investigated the impact of using mobile phones for nutrition surveillance. The majority of studies were implemented in sub-Saharan Africa and were published after 2009, suggesting a growing interest in the use of mobile phone technology for surveillance purposes in resource-poor settings.

Table 3.1 Summary of studies on the impact of using mobile phones for surveillance

Author	**Country**	**Purpose of surveillance**	**Aim of study**	**Setting**	**Technology**[b]
Nutrition					
Blaschke (2009)	Malawi	Nutrition surveillance	To develop a mobile phone-based system for growth monitoring and to assess its impact on data transfer and data quality	Community	Basic mobile phone/SMS/RapidSMS
Berg (2009)	Kenya	Nutrition surveillance	To develop and assess the use of mobile phones in nutrition programmes including growth monitoring	Community	Basic mobile phone/SMS/RapidSMS
Infectious disease (human and animal)					
Robertson (2010)	Sri Lanka	Livestock disease surveillance	To describe the design and implementation of a mobile phone-based surveillance system for animal diseases	Community	Smartphone/SMS/EpiSurveyor[c]
Madder (2012)[a]	Kenya and Benin	Livestock disease surveillance	To assess the feasibility of using mobile phones for early detection of animal diseases	Community	Smartphone/SMS/Survey to Go/Basic mobile

					phone/SMS/RapidSMS
Guo (2012)	China	Human infectious disease surveillance	To describe and assess the use of mobile phones for infectious disease surveillance in an emergency setting (after earthquake)	Community	Smartphone/SMS/custom software
Asiimwe (2009)	Uganda	Malaria surveillance	To assess the use of mobile phones to improve data collection and transfer during malaria surveillance	Health facility	Basic mobile phone/SMS/RapidSMS
Rajatonirina (2012)	Madagascar	Influenza surveillance	To describe the implementation of a mobile phone-based, sentinel site surveillance system for influenza	Health facility	Basic mobile phone/SMS/custom software
Safaie (2006)	Iran	Cholera surveillance	To assess the feasibility of using mobile phones for data collection and transfer in laboratory-based surveillance	Health facility	Basic mobile phone/SMS/custom software
Other					
Curioso (2005)	Peru	Adverse medical event surveillance	To describe the implementation of a mobile phone-based surveillance system to monitor adverse medical events and facilitate case management	Community	Basic mobile phone/SMS & voice/custom software
[a] paper presents two surveillance systems with similar aims but different mobile phone technologies [b] includes mobile phone device, form of data transmission, software [c] since 2013 called Magpi					

3.1.1 Data flow in mobile phone-based surveillance

The surveillance system that featured in the indentified studies all followed the same standard flow of information:

1. Data were collected by health workers[4] (integrated in routine data collection at the healthcare facilities or directly in communities by outreach workers)
2. Data were entered into the mobile phone device and transmitted to the central surveillance data base located at district or national level.
3. Data were collated, analysed and disseminated.

In three studies the data flow was purely one way from the cell phone of the data collector to the central database(Madder, Walker, Van Rooyen *et al*. 2012; Robertson, Sawford, Daniel *et al*. 2010; Safaie, Mousavi, LaPorte *et al.* 2006).

Surveillance systems in the other publications included some type of two-way data exchange. This could consist of: (1) an automatic and immediate feedback loop to the data collector that flagged up data entry errors; (2) an automated feedback loop with advice for the treatment of the patient based on data entered or calculation of nutrition indices (e.g.

[4] In all surveillance systems health workers conducted the data collection. In the context of the reviewed studies the term 'health worker' describes community nurses, community health worker, laboratory and veterinary staff.

weight-for-height, height-for-age, weight-for-age);[5] (Berg, Wariero and Modi 2009; Blaschke, Bokenkamp, Cosmaciuc *et al.* 2009); (3) immediate individualised feedback on a case-by-case basis by medical staff; (4) automated reminders to encourage health workers to submit surveillance data in a timely manner.

3.1.2 Technical features of mobile phone-based surveillance

The system architecture of mobile phone-based surveillance integrates the communication network (e.g. 2G, 3G, 4G), the mobile data capture devices (e.g. basic mobile phone, smartphone), and the software applications that facilitate data capture, coding, transmission and collation (e.g. via short message services (SMS), multimedia message services (USSD)). Depending on context-specific circumstances (e.g. cost limits, network coverage, environments) and surveillance needs (e.g. amount and detail of data, frequency of data collection) a different surveillance system can be built (see Appendix 2 for an overview of factors to consider when choosing mobile phone technology for surveillance).

In the identified studies, the majority of surveillance systems used low-cost basic mobile phones to collect data and standard 160-character text messages for data transmission to the central surveillance database (Rajatonirina, Heraud, Randrianasolo *et al.* 2012; Asiimwe *et al.* 2011); Berg *et al*. 2009; Blaschke *et al.* 2009; Safaie *et al*. 2006; Curioso *et al*. 2005). One system used additional voice files. Three studies employed more sophisticated smartphones with specialised applications and global positioning system (GPS) capabilities to facilitate geomapping[6] of the surveillance data (see Appendix 3 for an overview of different mobile phone devices for surveillance). Several surveillance systems were built using open-source software packages that can be downloaded free of charge and vary with regards to their levels of functionality (e.g. RapidSMS, EpiCollect). Other systems used commercial software packages (e.g. Survey to Go (Madder *et al*. 2012), Episurveyor, or custom-developed their own software applications (see Appendix 7 for the advantages and disadvantages of open versus commercial software in the context of low-income countries).

3.2 Methodological quality of available evidence

The methodological quality of the identified evidence was consistently low. Study designs were weak (e.g. no comparison/control groups, no baseline surveys) and study objectives were poorly defined in most of the reviewed studies. While all studies aimed to assess the feasibility of using mobile phone technology for surveillance, only a very few explicitly defined how feasibility would be assessed or provided measurable feasibility criteria from the outset.

In all studies, study populations (e.g. health clinics, outreach health workers) were selected purposefully and no (or only very limited) details on the characteristics of the samples were provided. Consequently, it was almost impossible to objectively assess the feasibility of using mobile phones for surveillance or draw conclusions regarding the impact. For example, educational backgrounds, familiarity with mobile phones, age and willingness to participate in the pilot studies can determine abilities, speed and ease in using mobile phone technology for data collection and transfer.

Ethical considerations (e.g. confidentiality, privacy, regulations concerning data sharing and security) are an important aspect of any health and nutrition surveillance. Human rights concerns accompanying HIV/AIDS surveillance drew international attention to the importance

[5] In order to determine whether a child is undernourished, the child's weight and height need to be compared to a healthy reference population. In population-based surveys/surveillance the comparison is commonly made by generation Z-scores (standard deviation scores). Z-scores describe how far a child deviates from the reference population.
[6] Geomapping is a popular data visualisation technique that displays data on geographical maps which allows, for example, visual identification of hotspots with a high prevalence of undernutrition or disease outbreaks.

of extending ethical concerns traditionally employed only for research to surveillance systems(Fairchild and Bayer 2004). The use of mobile phone technology for data collection and transfer is likely to increase the importance of ethical guidelines and considerations even further as data sharing (including accidental sharing) becomes easier. Ethical concerns were only raised in two of the identified studies; no study provided details on an ethical approval of the pilot.

Finally, in several studies the organisations that implemented the surveillance system were involved in the feasibility assessment. This might have compromised the objectivity of reporting as successful implementation is essential for future funding and public approval.

4. Evidence on the impact of using mobile phones to improve effectiveness surveillance

Improved data flow, enhanced data quality, lower costs and faster access to data are commonly highlighted as advantages of using mobile phones for surveillance of health and nutrition. Based on the identified studies, this section will analyse the evidence on the potential benefits of using mobile phones for surveillance.

4.1 Evidence on timeliness

The use of mobile phones promises to reduce the time latencies between data reporting in the community to data access via the central database. Time required both for mobile phone-based data collection and data transfer need to be considered.

4.1.1 Time required for data collection

Data collection and entry into a mobile phone-based interface was estimated to take between one and five minutes per record. There were some variations in the time requirements with regards to the amount of data collected and the complexity of data entry interface (e.g. specific SMS form coding system, questionnaire and automatic transfer into SMS format). Other factors that may affect the speed of data collection using mobile phones included familiarity with technology, comprehension of data collection interface as well as more practical issues such as size of screen and reflection when used in direct sunlight (e.g. during data collection in communities). None of the studies covered in this report compared the use of mobile phones for data collection and entry with pen-and-paper systems including pre-existing surveillance systems. Therefore, there is no conclusive evidence of the benefits of using mobile phones for surveillance systems in terms of speed of data collection.

4.1.2 Time required for data transfer

All studies emphasised that data transmission was significantly quicker and often in real time when mobile phones were used. The average reduction in data transmission delay was estimated to range from one day up to three months compared to alternative pen-and-paper approaches, although no direct comparison of the two approaches has been done. Limitations in the network coverage, delays in the server end and lack of electricity could delay data transmission and need to be considered.

4.2 Evidence on data quality

In the context of mobile phone-based surveillance, two approaches to the assessment of data quality emerged from the evidence: data entry accuracy and data completeness.

4.2.1 Data entry accuracy

Accurate data entry is the basis for high-quality surveillance data. However, accuracy is often compromised by time constraints for data collection, lack of concentration, misspellings and mistakes in the use of input codes and forms. Mobile phone applications can automatically capture many common data entry errors using pre-defined validation loops. The system can flag up errors in the central database and/or alert the data collectors, giving them a chance to immediately correct the error. Data entry error rates ranged from 2.8 per cent of all entered data (Blaschke *et al*. 2009) to 8.8 per cent (Asiimwe *et al.* 2011) and 10 per cent (Berg *et al*.

2009) in the included studies. Peaks in data entry errors were often observed when new health workers who were not familiar with the system joined the surveillance team (Berg *et al.* 2009).

4.2.2 Data completeness

Blaschke *et al.* (2009) estimate that up to 14 per cent of paper-based data collection forms need to be discarded due to incomplete data as a result of illegible handwriting, missing decimals and accidental omission of data entry fields. Data entry into a mobile phone device and validation feedback loops have been shown to significantly improve data completeness. Automated SMS messages to remind health workers to submit data regularly and in a timely manner also helped to improve data completeness (Rajatonirina *et al.* 2012; Asiimwe *et al.* 2011).

While the automatic feedback loops may have the potential to improve data quality and completeness, they cannot guarantee that the health worker will respond and correct or re-enter the data. Similarly, while mobile phones may help to improve data entry accuracy and completeness, the accuracy of the collected data (e.g. anthropometric measurements) depends on the technical skills of the health workers.

Many mobile phone-based surveillance systems also allowed system supervisors to monitor the data collection, work performance and workload of each health worker in real time and on an individual level. Necessary data corrections, feedback and additional training needs could be identified promptly and communicated immediately and may result in an additional quality improvement.

4.3 Evidence on costs

There is some evidence showing that mobile phone-based surveillance helped to reduce data collection and transmission costs, for example logistical costs for the transport of paper-based surveys, manual data entry and data cleaning. No average estimations for cost savings were provided in the available evidence.

While mobile phone-based data collection can facilitate cost-saving, initial set-up costs and running costs to operate the system can be high and need to be considered from early on to ensure long-term sustainability. Accurate estimation of the initial set-up and running costs is impossible based on the available evidence because most identified studies were heavily funded by external donors and/or benefited from partnerships with the private sector (e.g. provision of free mobile phone handsets, free data transfer, free hosting of surveillance database).

4.3.1 Initial set-up costs

Initial set-up costs are likely to include purchasing costs of mobile phone handsets. These costs were estimated at between £10 and £320 per unit, depending on technical sophistication and additional features such as GPS. Robertson *et al*. (2010) recommend using locally available mobile phone handsets as much as possible to reduce initial set-up costs. In two of the reviewed surveillance systems, health workers were asked to use their own mobile phones to collect and submit data. This approach was problematic in one of these studies (Safaie *et al*. 2006) as mobile phone ownership was low, whereas the health workers in the other study (Asiimwe *et al.* 2011) had no objections as no additional costs were incurred thanks to a toll-free number for data submission.

As described previously, several surveillance systems were built using open-source software packages and no initial costs were incurred for the purchase and renewal of software licences. Other systems used commercial software packages or custom-developed systems that are likely to pose considerable initial costs. Independent of the software packages used for the surveillance system, substantial expenses are likely to arise for the initial programming and customisation. Moreover, the need for continuous technical support of the software to address technical faults, system updates and modifications was highlighted in most studies. Asiimwe *et al.* (2011) estimated initial set-up costs for programming and technical support to be £31,700 (not including purchase of mobile phones or costs for health worker training) and continuous technical support costs of £260 per month for a malaria surveillance system in 140 clinics across two districts in Kenya. The authors speculate that in the long term high-priced technical support from programmers could be replaced by less expensive customer support teams without expert knowledge.

Costs also arose for the initial training of the health workers. Length of training ranged from a few hours up to several days, depending on the complexity of the mobile phone interface. Regular refresher training and training of new health workers pose additional costs.

4.3.2 Running costs

Data transmission costs are an important running cost that needs to be considered from early on as it can be a key determinant of health workers' willingness to contribute to mobile phone-based surveillance. In several pilot studies toll-free numbers were provided and health workers could submit data free of charge. Berg *et al*. (2009) describe free data submission as an essential requirement for long-term sustainability of the system. In one study, mobile phone credit for local health workers was provided temporarily. However, the logistics of distributing credit greatly increased the workload and there was a high likelihood that health workers used their credit for private calls and messages. Costs per one SMS sent were estimated to range from £0.01 to £0.2 (Madder *et al.* 2012; Asiimwe *et al.* 2011), £3 per month per user (Robertson *et al*. 2010), or £1.3 per month per sentinel site (Rajatonirina *et al.* 2012). As there are currently no international regulations or agreed ceiling levels for the price per SMS, the prices are likely to vary considerably between countries. Lack of price-regulating competition between network service providers (e.g. in case of one dominant provider) may also result in overpriced or randomly changing prices for data transfer.

Other running costs that need to be considered include costs for hosting the surveillance database, offline backup for the database and internet connectivity for the server. In one study, printing costs were highlighted as an important barrier to regular distribution of surveillance reports at the level of local health facilities.

4.4 Evidence on data analysis and visualisation

Evidence on the impact of mobile phones on the analysis and presentation of surveillance data were very limited. Rapid analysis and effective presentation of surveillance data is important to allow timely dissemination and fast review and comprehension of large amounts of data. However, the existing literature suggests that health and nutrition surveillance data are often underused, largely because of limited analytic capacity. Some of the mobile phone-based surveillance systems integrated some basic analysis and visualisation features that allowed calculation of simple descriptive statistics, generation of nutrition indices (e.g. Z-scores) and presentation of the data using tables, graphs and charts. In theory these in-built functionalities could support easier and quicker data analysis and presentation, although no evidence on experiences with these features was found.

Other surveillance systems applied standalone software packages to facilitate more advanced data analysis and visualisation such as geomapping. While additional standalone software packages provide more sophisticated tools for analysis and presentation, they can also bring about additional problems with software interoperability and compatibility of data formats.

A few surveillance systems had in-built features that auto-generated regular reports using the data, although the majority of surveillance systems either used additional more comprehensive reporting tools or did not specify any reporting plans. Reports varied depending on the intended audience (local-, district- and national-level stakeholders), frequency (e.g. daily, weekly, monthly) and medium used for communication (e.g. email, SMS or printed bulletin). Two studies (Asiimwe, Gelvin *et al.* 2011; Blaschke, Bokenkamp *et al.* 2009) provided stakeholders with continuous access to password-protected surveillance databases. No evidence on the use or impact of different reporting tools in mobile phone-based surveillance was identified.

5. Evidence on the empowering effects of mobile phones use for surveillance

Nutrition surveillance can empower governments by strengthening their capacity to keep track of the nutritional status of their populations, to respond in a timely manner and to target resources effectively. Surveillance can also empower the general public, civil society activists and community-based organisations by enhancing their capacity to make claims on agencies and governments with regards to their commitment to reducing undernutrition. Mobile phone technology may support and enhance these empowering properties of nutrition surveillance.

The evidence on the potential empowering effect of mobile phones in surveillance was very limited and none of the identified studies attempted to evaluate this aspect.

Community health workers in three studies (Berg *et al.* 2009; Blaschke *et al*. 2009; Curioso *et al.* 2005) described (in more or less formal qualitative interviews) how the two-way information exchange in their respective mobile phone-based surveillance systems empowered them to make independent decisions with regards to medical treatments, give advice to the caregivers/patients and also helped them to keep track of their patients. In another study the increased transparency of information flow between local, district and national levels was praised by local health workers; however, how far this affected daily practice was not mentioned (Asiimwe *et al.* 2011).

Evidence on how mobile phones might help governments to respond more quickly and effectively is rare. The infectious disease surveillance system described by Rajatonirina *et al*. (2012) was the exception. This sentinel site surveillance system was established and run by the Ministry of Health in Sri Lanka. The study suggests that the Ministry responded promptly to alerts submitted from local sentinel sites. However, the reason for the rapid response most probably lies in the strong commitment of the government to the system and not in the effectiveness of the technology. In another study, stakeholders responded in an 'ad hoc' manner to gaps and problems highlighted by the surveillance system (Asiimwe *et al.* 2011). Based on these observations, the authors recommended that clear protocols with guidelines about when to respond and who should respond to surveillance data are critical, especially when national scale-up of the system is planned. Of course, the underlying requirement is that governments and other stakeholders have the capacity and willingness to actually use the surveillance data once they are available. It might be necessary to build this capacity to use surveillance most effectively.

6. Challenges of using mobile phones for surveillance

A number of technical, financial and ethical challenges can inhibit the successful implementation and sustainability of mobile phone-based surveillance.

6.1 Technical challenges

6.1.1 Network coverage

Limited or fluctuating network coverage was a challenge for many surveillance systems. Systems that used automated feedback algorithms for two-way communication were particularly affected by network downtimes. In one study, health workers were trained to collect data using pen and paper in case of lack of network coverage and to enter and submit the data as soon as the network became available (Asiimwe *et al.* 2011). In surveillance systems that employed more sophisticated smartphones, data could be stored and automatically forwarded as soon as the network became available (Robertson *et al.* 2010).

In two studies (Madder *et al.* 2012; Blaschke *et al.* 2009), problems with internet connectivity affected access to the surveillance database, which could disrupt reception of transmitted data as well as access to the database by stakeholders.

6.1.2 Electricity coverage

Unreliable access to electricity, especially in remote areas, can prevent regular recharging of mobile phones and may temporarily shut down the entire surveillance system. Electric power downtimes can also affect the server that hosts the surveillance database. Solar-powered mobile phones were a promising approach to ensure charged phones in one study that described disease surveillance in emergency settings (Guo and Su 2012).

6.1.3 Technical support needs

Sufficient technical skills of participating health workers were important for the smooth operation of surveillance systems. Many studies highlighted the constant technical support needs that included technical training and supervision. Especially in contexts where mobile phone ownership was low (Safaie *et al*. 2006) and familiarity with mobile phones minimal, training was essential and time-consuming. However, as mobile phone penetration keeps increasing, this challenge may solve itself soon. Constant technical support was also needed to address problems with the software and monitor the surveillance database. In the case of externally funded surveillance, employing technical experts locally might help to save money and contribute to local capacity building (Asiimwe *et al*. 2011).

6.1.4 Software problems

Apart from initial problems with the set-up of the software (with regard both to technical issues and comprehension by data collectors), difficulties in modifying the software to include new variables and necessary updates could be a challenge for some systems. Updates were especially problematic and cost-intensive in systems that used mobile phones with pre-installed applications. In this case, all phones had to be recalled to install a new version of the software (Guo and Su 2012).

Software compatibility with different brands of mobile phones was limited in a livestock disease surveillance system in Sri Lanka (Robertson, *et al.* 2010). Consequently, not all animal health workers could use their own handsets and new phones needed to be purchased. Modifications in the software could eliminate this shortcoming and help to save costs.

6.1.5 Human capacity constraints

Mobile phone-based data collection was often an additional burden for already overstretched health workers and keeping them motivated could be challenging. In one study (Asiimwe *et al.* 2011), several health facilities refused participation in the pilot study of a malaria surveillance system as the reporting requirements were perceived to be too work- and time-intensive. In another study (Rajatonirina *et al.* 2012), health workers asked for incentives for their voluntary participation as it would increase their daily workload. The study team decided to provide medical equipment to the health facilities and to offer medical training opportunities to the health workers directly in exchange for their participation. The health workers who collected the data in several other systems described how the two-way information exchange with immediate provision of advice for the case management of patients supported their work and motivated them to participate in the pilot. However, the novelty of these information exchanges might soon end and messages might be perceived as less useful, especially if the same medical advice has to be given repeatedly.

6.2 Financial challenges

Continuous and secure funding is a key factor in ensuring long-term maintenance of all surveillance systems, including mobile phone-facilitated surveillance. Both initial set-up costs and running costs of mobile phone-based surveillance need to be considered when developing a viable financial model. For a detailed discussion of the different cost factors see Section 4.3.

Several of the pilot studies included in this evidence review ceased to exist or were not scaled up nationwide due to lack of funding once external funders had left. This emphasises the importance of the development of sustainable business models that do not rely on constant external funding but achieve self-sufficiency, for example via innovative partnerships with the private sector.

6.3 Ethical challenges

Concerns about data confidentiality, data ownership and security were raised in a few studies (Guo and Su 2012; Robertson *et al.* 2010). In this context Guo *et al*. emphasised the importance of clearly defining from the outset how data security and confidentiality will be ensured at every level of the system.

7. Factors that enable mobile phone-based surveillance

Based on the reviewed evidence, three factors that can support the successful implementation, long-term sustainability and scale-up of mobile phone-based surveillance were identified: a supportive local government, a functioning healthcare system and a strategic partnership with the private sector.

7.1 Supportive local governments

Several studies highlighted the importance of developing the surveillance system together with key stakeholders from the local government and of addressing surveillance needs identified by these stakeholders (Asiimwe *et al.* 2011; Robertson *et al*. 2010; Blaschke *et al.* 2009). Purely funder-driven surveillance systems were often discontinued when governments were not willing to fund the systems once external funding ceased. Equally unsuccessful were systems that were predominantly technology- or expert-driven without input from local stakeholders and alignment with the local needs and realities in the development stages. In the ideal case, the mobile phone-based surveillance system should be aligned with already existing surveillance systems, as opposed to being implemented in parallel or competion with them. Robertson *et al.* (2010) observed how the initiation of a mobile phone-based animal health surveillance system in Sri Lanka initially provoked some confusion and also fear among stakeholders who experienced competition from the new system. It was necessary to clearly demonstrate how the two systems could complement each other.

7.2 Functioning healthcare system

To preserve the confidence of local health workers and more senior health authorities on the added value of work-intensive surveillance, it is important to have a healthcare system with the capacity, willingness and resources to both collect the surveillance data and to respond to problems highlighted by the surveillance system. Mobile phones may enable more effective and efficient surveillance, but they cannot replace, change or fix poorly functioning healthcare systems. Equally, the mobile phone technology employed to facilitate surveillance needs to fit into the local realities of the healthcare system and its staff. For example, an understanding of how data are currently used, what the challenges are in the uptake of data, and what alternative formats might facilitate uptake all need to be taken into consideration.

High staff turnover and attrition could pose challenges, especially for rural healthcare systems, as constant training and supervision of new staff members in the operation of the mobile phone-based surveillance may become indispensable (Guo and Su 2012; Rajatonirina *et al.* 2012)

7.3 Strategic partnership with the private sector

Effective partnerships with the private sector are discussed as a promising approach to ensure lasting affordable operation of a mobile phone-based surveillance system and support scalability. Partnerships may help the surveillance system to become more self-supporting and less dependent on external funding. Partnerships between the private and public sector are not without frictions as different operating cultures, pace of work and overall objectives come together (Silvius, Sheombar and Smit 2009). To be able to build a long-term and trusting relationship it is important to acknowledge these differences honestly and clearly define the objectives and responsibilities of each partner. A few of the reviewed studies had established partnerships with mobile network providers and technology companies to support the pilot study. However, these partnerships were exclusively one-time funding streams and included, for example, the provision of free-of-charge mobile phone devices or network coverage. To ensure sustainability and to support scale-up, mutually beneficial partnerships that go beyond social corporate responsibility and draw on the abilities and strengths of the different partners need to be established early on in the surveillance system and maintained.

Sustainable business models for mobile phone-based surveillance may also include partnerships with other industry partners such as pharmaceutical companies or private service providers (e.g. private health clinics). Multiple partnerships with different private partners might also be possible. However, there are drawbacks to such partnerships, such as ethical considerations (e.g. data security and ownership), that need to be considered carefully.

8. Conclusions and recommendations

In recent years mobile phone technology has received growing attention from the development field. In particular, it is believed that mobile phones may have the potential to make nutrition surveillance more effective and affordable in resource-poor settings. This report critically assessed and synthesised the existing evidence base. The main conclusions can be summarised as follows.

1. There is a lack of hard evidence on the impact of using mobile phones for surveillance (and especially nutrition surveillance)
Evidence on the impact and use of mobile phone technology for surveillance is scarce and only two studies on the impact of mobile phones on nutrition surveillance were identified. The evidence that is available is of poor methodological quality, based on small pilot studies and mainly centres on feasibility issues. To fully realise and understand the potential of mobile phones for surveillance and to design sustainable and scalable surveillance systems, this evidence gap needs be addressed by well designed, comprehensive evaluation studies with clearly defined objectives.

Based on the existing evidence from the identified studies the following tentative conclusions can be drawn.

2. Mobile phones may make nutrition surveillance timelier
Although no direct comparison has been made, descriptive evidence suggests that data transfer and collation are significantly faster in mobile phone-based surveillance compared to surveillance using pen-and-paper. Depending on whether network coverage is available or not, data can be available in nearly real time.

3. Mobile phones may help to improve data quality in nutrition surveillance
There is consistent evidence showing that automated feedback loops and SMS reminders can help to substantially improve both data entry accuracy and completeness of the data. Reliable and high-quality surveillance data are essential to inform appropriate decisions, monitor change and the impact of programmes aiming to reduce undernutrition.

4. There is a lack of comprehensive cost-effectiveness evaluations of the use of mobile phones for surveillance
There is currently no convincing evidence on the cost-effectiveness of mobile phone-based surveillance systems. While substantial costs may be saved during the collection, transfer and collation of data, the initial start-up costs and operating costs might outweigh those cost savings. To understand the potential financial benefits of mobile phone-based surveillance, cost-effectiveness evaluations need to be included in future studies.

5. Need for more focus on analysis, visualisation and reporting of surveillance data
The functional and structural possibilities of mobile phones may be a powerful tool in the timely and user-friendly analysis, visualisation and reporting of surveillance data. Unfortunately, the focus of all studies was on data collection and transfer and the actual data utilisation received only minimal attention. Given that underuse of surveillance data is a huge challenge, a better understanding is urgently needed of how mobile phones may improve this essential component of surveillance.

6. There is no evidence on the empowering effect of mobile phones use in surveillance systems
Although evidence suggests that mobile phones may empower local health workers via a two-way information exchange and may strengthen the capacity to respond in a few

receptive stakeholders, no study attempted to assess the empowering effect of mobile phones further. For example, there was no evidence on the pathways of empowerment via surveillance and how these might be strengthened by the use of mobile phones. Future studies are urgently needed to explore and evaluate the empowering effect of mobile phones in nutrition surveillance.

7. Mobile phone-based surveillance faces technical, financial and ethical challenges
The identified technical, financial and ethical challenges reflect those discussed widely in the literature on mobile phone data collection in developing countries (Tomlinson, Solomon, Singh *et al.* 2009; Lewis and Chretien 2008; Kaplan 2006). To ensure long-term maintenance of a mobile phone-based surveillance system and to allow successful scale-up, it is important to address these challenges from the outset of the surveillance.

8. Government support, a functioning healthcare system and strategic partnership with the private sector are important for sustainability and scale-up of mobile phone-based surveillance
Nutrition surveillance can only be effective and fulfil the overarching aim of reducing undernutrition if it is sustained. Support from the government, including alignment with local surveillance needs and a strong healthcare system that can respond (and in many cases) deliver surveillance is important for sustainability and to support scale-up. A strategic and effective partnership with the private sector may be a promising approach for the design of a sustainable and scalable surveillance system. However, no evidence on what such a partnership would look like in the case of surveillance could be identified in this evidence review and there is urgent need for further research in this area.

In conclusion, despite the general lack of high-quality evidence from evaluation studies and many unknowns (e.g. cost-effectiveness of mobile phone-based surveillance, how to develop a sustainable business model), the available evidence suggests that mobile phones may play an important role in nutrition surveillance by reducing the time required to collect data and by enhancing data quality. Both of these are essential for reliable and effective nutrition surveillance but long timescales and poor data quality are often shortcomings of traditional paper-based systems. Mobile phone technology also seems to have considerable but still underused capacity to support effective analysis, presentation and communication of surveillance data to stakeholders at local, district and national levels. A much better understanding of the barriers to and enablers for bringing this capacity to fruition is needed. The empowering potential of mobile phone technology very much remains an attractive yet empirically unsupported idea.

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APPENDIX 1: Mobile phone subscriptions in the 36 countries with the highest burden of undernutrition

	Country Name	2011 (per 100 people)
1	Afghanistan	54.26
2	Angola	48.38
3	Bangladesh	56.48
4	Burkina Faso	45.27
5	Burundi	14.46
6	Cambodia	69.90
7	Cameroon	52.35
8	Congo, Dem. Rep.	23.13
9	Côte d'Ivoire	86.42
10	Egypt, Arab Rep.	101.08
11	Ethiopia	16.67
12	Ghana	84.78
13	Guatemala	140.38
14	India	72.00
15	Indonesia	97.72
16	Iraq	78.12
17	Kenya	64.84
18	Madagascar	38.28
19	Malawi	25.07
20	Mali	68.32
21	Mozambique	32.83
22	Myanmar	2.57
23	Nepal	43.81
24	Niger	27.01
25	Nigeria	58.58
26	Pakistan	61.61
27	Peru	110.41
28	Philippines	91.99
29	South Africa	126.83
30	Sudan	56.25
31	Tanzania	55.53
32	Turkey	88.70
33	Uganda	48.38
34	Vietnam	143.39
35	Yemen, Rep.	47.05
36	Zambia	60.59

Source: World Development Indicators (http://data.worldbank.org)

APPENDIX 2: Factors to consider when choosing mobile phone technology for surveillance

The factors affecting the decision of which mobile phone technology to choose fall into two groups: (1) context-related factors, and (2) surveillance system-related factors. The first group of factors are those determined by the context in which the project will be developed (e.g. the coverage and the quality of the mobile network). The second group of factors are those related to the type of surveillance system (e.g. complexity of data to be collected).

It should be noted that both context- and surveillance system-related factors affect the amount of initial and long-term funding required to implement the surveillance system. At the same time, the type of system will be limited by the level of financial resources available within a given context.

1. Context-related factors

i. *Network coverage:* The local network coverage determines whether it is possible to transmit data at the moment of collection (in real time). If network coverage is not available, data need to be stored in the device and transferred as soon as network coverage is available.

ii. *Type of network:* Different types of mobile phone communication networks can be differentiated (e.g. second generation (2G), third generation (3G)). The type of network determines the efficiency of data transmission as well as which mobile phone device can be used (e.g. basic mobile phones, smartphones).

iii. *Technology-literacy level*: Mobile phone technologies need to be appropriate for the local context in which they should be used. In settings with low mobile phone penetration and low levels of technology literacy, basic mobile phones with low complexity might be more acceptable and require less training than more sophisticated smartphones.

iv. *Geography:* Network coverage can be affected by the geographic features of a setting. For example, mobile phone-based surveillance in mountainous areas might be more challenging than surveillance in flat areas.

v. *Existing storage infrastructure:* The availability of data storage capacity for the surveillance system determines the format in which the surveillance data can be stored, as well as the software needed to store the data. This can lead to a trade-off between data compression and accessibility (higher rates of data compression may lead to less efficient ways of accessing it).

2. Surveillance system-related factors

i. *Feedback capacity*: Surveillance systems with one-way information flow require different mobile phone technology from systems that have two-way information exchange. Two-way information flow as part of a surveillance system could include (1) a feedback loop to the data collector to flag up data entry errors, (2) a feedback loop with advice for the provision of a service based on data entered or calculation of indices, (3) immediate individualised feedback on a case-by-case basis, or (4) automated reminders to encourage submission of surveillance data in a timely manner.

ii. *Real-time surveillance:* Availability of surveillance data in real time is especially important for early warning and to highlight potential nutritional crises. Real time systems need to have the capacity to transfer data to the central database immediately after data collection.

iii. *Complexity of the data collected:* Surveillance systems can vary in the amount and complexity of data collected. The more complex the data, the larger the amount of storage capacity or transmission capacity of the device/system. This will also affect the training needs of the field worker.

APPENDIX 3: Overview of different mobile phone devices and other data capturing methods for surveillance

Data capture device	Costs[a] *	Network[b]	Operational criteria[c]	Speed of transmission[d]	Ease of use[e]	Penetration[f]	Analytic capability[g]	Data capture mode[h]
Traditional pen and paper	Depends on delivery method	Manual	Can be used under any circumstance. Transportation of data complicated.	Stored and transferred later.	Depends on literacy levels of field workers.	Global	Very flexible, though it may be time-consuming	Store-and-forward
Satellite phone	£100	Data kit	Usually they require a large retractable antenna, which may raise transportation issues. Most modern devices are the size of a smartphone.	9.6kbps Data/voice speed transmission needs to be in line with satellite networks and clear signal.	Requires outdoor line-of-sight to satellite (powerful devices may work under thin roofs). Training: 1 day.	Global	None	Real-time/Store-and-forward
Satellite broadband	£850	Satellite terminal		240–492 kbps (depending on satellite terminal).	Requires outdoor line-of-sight to satellite (powerful devices may work under thin roofs).	Nearly Global	None	Real-time / Store-and-forward
Fixed-line telephone – USB	£25	USB modem		48kbps		14%	None	Real-time

Data capture device	Costs[a] *	Network[b]	Operational criteria[c]	Speed of transmission[d]	Ease of use[e]	Penetration[f]	Analytic capability[g]	Data capture mode[h]
Fix line – telephone DSL modem	£40	DSL modem		384kbps		2%	None	Real-time
Mobile phone								
Basic mobile phone	£10 – £300	2G	Limited data transmission capability (SMS), low battery life.	33.6kbps	High familiarity, low training needs.	72%	Limited	Real-time
Smartphone	£220 and more	3G and higher	Higher data transmission capacity.	800kbps	Lower familiarity, higher training needs.	49.5%	Relatively high	Real-time/Store-and-forward
PDA (personal digital assistant) (e.g. Palm OS, MS Pocket PC)	£250	None	High data storage capacity.	Stored and transferred later.	Training: 1–3 days.	NA	Can host analytic applications (see above)	Real-time/Store-and-forward
Network tablet/Kindle	£180	G3/WiFi	Larger screen, relatively fragile. Battery may require quite frequent recharging. Rebooting system may be complicated.	Stored and transferred later. Depends on the type of data, the software used to collect the data, and the type of network (G2, G3).	Training:1–3 days. Its use may be complicated as the device may require downloading updates to improve its performance.		Can host analytic applications (see above)	Real-time/Store-and-forward

a. *Costs:* Refers to hardware costs only.
b. *Network requirements:* Communication network required to transmit surveillance data to central server, e.g. 2G, 2.5G, 3G and higher.
c. *Operational criteria:* This included characteristics of device (e.g. average size, weight), battery life (need for electricity), availability in developing countries (e.g. new web Kindle is probably not marketed in many low-income countries), resistance to environmental stresses (e.g. extreme weather such as heat, rain, dust, dirt, falls).
d. *Speed of data transmission:* Real-time submission of data versus later submission.
e. *Ease of use:* More complex technologies require more intensive training and might be a burden for fieldworkers without technology experience (e.g. estimated training time based on literature). This criterion also addresses the maintainability of the system (for instance, how easy it is to restore the system in case of failure).
f. *Penetration:* Devices with high penetration may be more convenient than other devices that are not as popular within a population.
g. *Analytic capacity:* Additional applications can be installed in modern devices to provide immediate feedback to the fieldworker. For instance, even offline, the device used to collect health indicators may provide an alert if the individual presents a health problem based on the data collected.
h. *Data Capture Mode*: Equipment is 'Real time-enabled' if it is able to send the information right after being collected. Otherwise, the data collection process will rely on the mobile's capacity to store the data and send them when connectivity is available.

APPENDIX 4: Overview of different software platforms for surveillance systems

	Costs	Network	Operational criteria	Ease of use	Data format[a]	Configurability[b]
FrontlineSMS	Free of charge.	2G			SMS message	No information
RapidSMS	Free of charge.	2G	No software needs to be installed on phone.		SMS message	No information
Episurveyor (Magpi)	Free of charge (up to certain level). Widely used in developing countries, especially Africa.		Highly customisable, independent case studies.	Charges may apply for scale-up.		No information
Open data Kit (ODK) – Android	Free.	GPRS, WiFi	Open-source software for Android devices.	Three-step set-up process. Forms design requires experience on XLSForms.	Text, video, Audio, GPS, Barcodes	The set-up can easily be adapted to different environments (i.e. languages)
Java Rosa	5 users – Free. 10 users – £10/month. Unlimited users – $200/month.	GPRS	Open-source software for a large spectrum of devices (from large tablets to low-end smartphones).	Require XForms for forms design.	Limited by headset and network	
Nokia Data Gathering	Free.	GPRS, WiFi	Open-source software. Works on mobiles with Java or Windows software.	Source code is available online. Questionnaire should be created in a survey editor.	Text, Images, Video, Audio, GPS	System set-up is relatively simple. Available in English, Portuguese and Spanish
EpiCollect	Free, open-source. Unlimited data space.	GPRS, WiFi, 3G	Store and later transfer possible,for Android and iPhone.	Creates forms also. Does not require set-up on a server (although this is possible too).	Text, Images, GPS	
openXdata (Java Phones)		GSMS (SMS), GPRS (WAP), Bluetooth	For Java-enabled phones, used in early warning systems.		Text, Images, Video, Audio, GPS	

[a] *Data format:* Some software is able to process any type of data. Others can only handle alphanumeric information.
[b] *Configurability:* This includes issues around ease of adaptability of the system to different environments and in response to change (e.g. in response to emergencies, climate shocks). Is there a community of users that can help or is a specialised ICT expert needed? In-country configurability likely.

APPENDIX 5: Comparison of the capacity of second and third generation mobile phones for nutrition surveillance

	2G Network (1)	(2)	3G or Above Network (3)
ICT-option	Simple 2G mobile phone Open-source software (e.g. RapidSMS/FrontlineSMS)	Simple 2G mobile phone – Java-enabled (JavaRosa, Nokia Data Gathering, openXdata)	Smartphone (3G or above); applications available depend on technology and operating system*
Data collected	SMS-based, nutritional status, service coverage (sampling difference)	Simple questionnaires, more complex data, skipping patterns etc.	Simple questionnaires, more complex data, skipping patterns etc.
Use of data	Early warning, highlighting hotspots, coverage/quality assessment	Use of data in (1), deeper analysis of covariates and trends	Use of data in (2)
Allows feedback capability	Yes	Yes	Yes
Advantages	Very real-time data collection, quality check	Runs in very simple mobile phones; does not require additional software for simple analysis	Network allows faster data transmission; does not require additional software for simple analysis
Shortcomings	Simple data, though coding may be difficult; requires additional software for analysis	Network may be slow for transmission of large amounts of data; may need larger amounts of storage space in both handset and server	Handsets may be more expensive and difficult to handle; may require technical assistance; may need larger amounts of storage space in both handset and server

APPENDIX 6: Overview of compatibility of different software platforms across mobile phone devices

Software for Data Collection	Network Generation					
		Smartphone (3G or above)				
	2G	Mobile Operating System				Notes
		Android	iOS	Windows	Linux	
Frontline SMS/RapidSMS	X	X	X	X	X	As these software are based on SMS, they can be implemented on any mobile phone 2G or above
ODK		X	X	X	X	
Java Rosa (provided that device is Java-enabled)	X	X	X	X	X	Provided that device is Java-enabled
Nokia Data Gathering	X	X	X	X	X	1. Needs Java support 2. A version for Windows Mobile 7 or above is also available
Episurveyor		X	X	?	?	
Epicollect		X	X			
openXdata (at least Java-enabled)	X	X	X	X	X	1. Runs mainly with Nokia phones, which use a different operating system 2. As long as the phone is Java-enabled, openXdata will run

APPENDIX 7: Advantages and disadvantages of using open-source software

Advantages	Disadvantages
Lower costs (no licence needed): it is free to use, distribute and modify.	More responsibility, expertise and English language skills required from local software support to follow quick development and changes in software (often many parallel developments); higher local expertise in software needed (more established open-source software is more transparent).
Flexibility, adaptability and modification (increased configurability to context and changing needs).	Less compatible with other software: there is a shortage of applications that run both on open-source and proprietary software.
It is more secure, as anyone may be able to fix bugs with the help of open-source community/independently in-country.	Many of the latest hardware devices do not support open-source platforms.
Can be made compatible with other programs (e.g. analysis software) and surveys (dataset merging).	
Potential to support capacity building in developing countries (via collaborative problem solving).	
More control over the data and platform.	

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